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REPORT OF THE FIFTH NORTH PACIFIC
ALBACORE WORKSHOP

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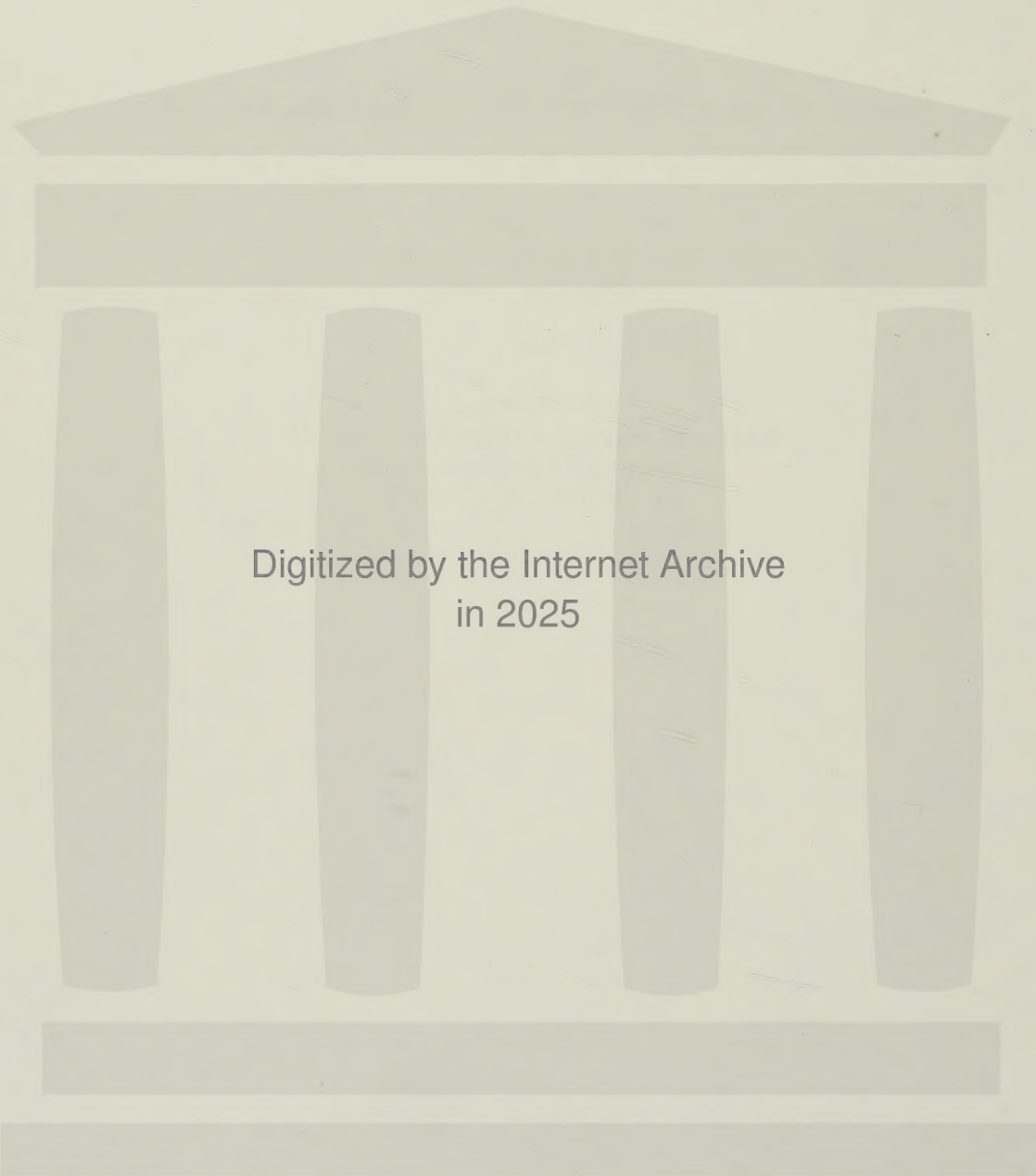
REPORT OF THE FIFTH NORTH PACIFIC ALBACORE WORKSHOP

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REPORT OF THE FIFTH NORTH PACIFIC ALBACORE WORKSHOP

I. INTRODUCTION

The Fifth North Pacific Albacore Workshop met from June 30 through July 3, 1980 at the Southwest Fisheries Center, La Jolla. The North Pacific Albacore Workshop series began in 1974 as an informal agreement between the Far Seas Fisheries Research Laboratory (FSFRL) and the Southwest Fisheries Center (SWFC) and includes scientists from Canada, Taiwan, state agencies, and universities. The purpose of the 1980 Workshop was to investigate the population dynamics, biology and ecology associated of the North Pacific albacore.

Dr. Izadore Barrett, Director of the Southwest Fisheries Center, welcomed the participants (Appendix A) to the Southwest Fisheries Center and expressed his support for the Workshop and its goals. Dr. N. Bartoo assumed the role of Chairman of the Workshop and appointed Mr. S. Kume to help him as rapporteur. The Workshop Agenda (Appendix B) was adopted by the participants and 16 working papers (Appendix C) presented to the Workshop were distributed.¹

II. REVIEW OF CURRENT RESEARCH

Research on North Pacific albacore falls into two general categories: biological and oceanographic investigations and analyses of data derived from fishery statistics.

¹Working papers used at the 5th North Pacific Albacore Workshop were intended for discussion at the Workshop and are available for dissemination at the discretion of each author. Individual authors should be contacted for copies of working papers. Working papers are referenced in the text as NPALB/80/ , etc.

Prominent among biological studies are tagging results which provide information on the interrelationships of albacore occurring in various regions of the North Pacific. Shiohama (NPALB/80/4) reviewed results of Japanese tagging conducted in the Northwest Pacific during 1972-79 and stressed evidence suggesting that juvenile albacore in that region were from a single unit which may not contribute significantly to the North American fishery. He further suggested that the extensive evidence of migrations from waters off North America to those adjacent to Japan, points to a one-way migration, as opposed to the hypothesis of a two-way migration. Shiohama's interpretation of United States tagging results also disputes the hypothesis of separate northern and southern groups of albacore in the eastern Pacific. In discussion of the results it was contended by U. S. participants that the Japanese tagging results are not necessarily in conflict with those of the United States in that, especially in recent years when albacore have been apparently delayed in their departure from Japanese coastal waters, many fish may have failed to reach North American waters before autumn cooling began and therefore no tags were recovered in the U. S. fishery. Furthermore, the complexity of albacore movements in the eastern Pacific makes it difficult to confirm or deny the existence of southern and northern groups. In any event, further tagging combined with some biochemical analyses are deemed desirable to verify the presence and the degree of independence of the two groups of albacore in the eastern portion of the North Pacific.

Laurs and Nishimoto (NPALB/80/3) presented results on the evaluation of otolith daily growth ring increments. It is concluded that for practical purposes, the rings are indeed deposited daily and this opens the way to resolve the controversy concerning the size of albacore on their first and second birthdays. The ageing procedure, however, is extremely tedious and time consuming. A less arduous technique of age determination obviously would be much more preferable. To this end, further (but still preliminary) results presented by Ketchen (NPALB/80/12), on age determination of albacore from growth rings seen in cross-sections of dorsal finrays, are viewed with optimism, but the method is not free of difficult problems. Through cooperation of various fisheries agencies, finray samples are now at hand from several areas of the North Pacific and from a wide size range of fish.

Collection of more samples and reexamination of existing material is required to resolve current difficulties. In addition further study of tetracycline-injected specimens is urgently required to calibrate the method and verify annual deposition of a single growth check.

Laurs et al. (NPALB/80/3) presented new information from ultrasonic tracking of albacore. Telemetered data (covering up to 30-hour time spans) on swimming depth and water temperature show that, contrary to earlier information and assumptions, albacore may spend relatively lengthy periods beyond the bounds of their so-called preferred temperature range (15° - 20°C). These short-term studies revealed that tagged fish will not only occupy water of 10° - 13°C but will make rapid sorties over a depth range in which temperature change is as much as 5°C . Telemetered data also showed apparent day-night depth preferences and differences in the behavior of assumed migrating versus nonmigrating fish. This new information has implications in understanding of variations in the availability of albacore to conventional surface fishing gears.

Yield-per-recruit studies by Bartoo (NPALB/80/1) along with investigation by Weber (NPALB/80/2) of possible interaction among the three principal North Pacific fisheries were presented. Both fields of investigation depend on age structures generated from the von Bertalanffy growth equation. Reliability of the conclusions, therefore, hinge in part on the accuracy of assumed growth parameters. Some revisions in results can be anticipated as better information on the latter emerges from current age and growth studies.

III. REVIEW OF STOCK STRUCTURE

The stock structure of North Pacific albacore was discussed. Of particular interest were studies that indicate North Pacific albacore exhibit complex migratory patterns and, as juveniles, may form separate groups. These studies, involved (1) detailed release-recapture information from the U. S. tagging program, (2) differences in sizes at the same ages for different areas, (3) a possible association between catch levels in the North American fishery and the timing of the Japanese pole-and-line fishery and (4)

other biological characteristics indicated by biochemical analyses, nucleid concentrations, etc. which some scientists felt were evidence of two groups, especially in the eastern north Pacific; a southern and a northern group. One of these hypothesized groups appears to enter the U. S. coastal fishery south of about 40°N and the longline fishery east of about 180°. Efforts to track this southern group after the U. S. fishing season have been made but so far without success. With regard to the northern group, trans-Pacific migrations between eastern and western North Pacific are evidenced by the U. S. tagging results, implying that the northern group is highly associated with the fish caught by the Japanese pole-and-line and longline fisheries in the western North Pacific and possibly with the developing U. S. jig fishery in the central North Pacific. Using a summary of Japanese tagging results during 1971-79, NPALB/80/4 hypothesized the seasonal movement of young albacore (age 3 and 4 fish), in which some, but not all, of the fish in the western North Pacific migrate into the easternmost margin of the North Pacific. This was based on results of tagging conducted by Japan in the eastern North Pacific.

Information available at this time is inadequate to confirm the two-group hypothesis. Additional work is necessary to determine to what extent these groups remain separate as juveniles and, more importantly, as spawning adults, and to determine how oceanographic and other factors might affect the hypothesized separations.

IV. REVIEW OF CURRENT FISHERY

U. S. Fishery

The 1979 U. S. albacore fishery was reviewed in NPALB/80/3. The 1979 albacore fishery off the west coast of the U. S. and northern Baja California, Mexico was one of the poorest on record with landings totalling 4990 MT. This compares with a 1978 seasonal total of 16782 MT, and a seasonal 10-year average of about 20865 MT. Several factors appeared to have contributed to the low albacore landings in 1979, including (1) the late arrival of fish into U. S. north and south coastal waters; (2) weak or nonexistent temperature fronts along much of the U. S. coast; (3) high winds and rough seas hampering fishing effort notably off central and northern California; (4) fish not biting, particularly in the Cortez Bank area and off Central California; (5)

low availability of 5.5 to 6.8 kg fish off California which normally make up a significant portion of the U. S. catch; and (6) closure to U. S. fishermen of waters within 200 miles of the coast of Canada where there was apparently a significant amount of fish. Standardized CPUE for the 1979 U. S. albacore fishery was the lowest on record. In addition to the coastal fishery in 1979, a distant water fishery with 25 to 27 U. S. vessels fishing near the international date line in the general area of the Japanese pole-and-line fishery landed a total of 1642 MT of albacore. Thus far this year, approximately 50 U. S. jig vessels are fishing in this mid-Pacific area.

Japanese Fishery

Information on Japanese albacore fisheries was reviewed in NPALB/80/8. The recent winter longline fishery occurred as usual in the area of 26-32°N and 137-150°E from December 1979 to March 1980. There, the hook rate for albacore considerably exceeded that of the past two seasons. Catch in the northern portion of the fishing ground was composed mainly of fish in the 70-80 cm size range (age 3 to 4) while those fish caught further south were medium and large (age 4 and older). The Japanese longline catch has stabilized between 10-15,000 MT in recent years. Landing totals for 1979 are not yet available.

The 1980 pole-and-line fishing season began as usual in April harvesting fish of more than 80 cm. At time of reporting the Emperor Sea Mount fishing ground had not yet developed on a full scale, although some success had been reported on age 4 fish. Catches in previous fisheries (1978-79 pole-and-line season and 1979-80 winter longline season) indicate that the 1976 cohort may have been a dominant year class. Total catches for the summer pole-and-line fishery may reach approximately 40,000 MT, or 4,000 MT higher than last years summer pole-and-line landings. Total pole-and-line landings for summer-autumn fisheries for 1979 were an estimated 43,000 tons.

The incidental catch of albacore by the Japanese large meshed drift gill net fishery in 1978 totalled 4,000 MT, a sharp increase from the 1977 landings of 688 MT. An artisanal fishery, which has historically accounted for less than 1,000 MT of albacore, harvested 2,000 MT during 1978.

Other Fisheries

Catches of North Pacific albacore by Korean and Taiwanese longliners based in American Samoa were reviewed by Wetherall (NPALB/80/14). These catches are still insignificant in terms of impact on the North Pacific albacore stock. North Pacific albacore from American Samoan based Korea longliners totalled 13 metric tons in 1977 and 4 metric tons in 1978. Landing totals for the Taiwanese vessels in this area were reported by Yang (NPALB/80/9). Taiwan began fishing albacore with measurable effort on the high seas of the North Pacific for the first time in 1977. Albacore catches in this multi-species longline fishery totalled 551, 6 and 35 MT for the years 1977, 1978 and 1979 respectively. Albacore catch for the first quarter of 1980 is an estimated 150 MT. Number of vessels operating in the fishery in the entire Pacific was 309 in 1977, 302 in 1978, 157 in 1979, and 169 thus far in 1980. Landings for the Taiwanese inshore tuna longline fishery is estimated to be in the range of 15-47 MT annually since 1964.

Canadian catch of albacore in 1979 was estimated at 520 MT substantially more than in the preceding 4 years. This was despite a late start, inclement weather and an imposition by the United States of an embargo on tuna products from Canada. The fishery was concentrated along a temperature front off the entrance to Queen Charlotte Sound. Most of the catch was made in the last two weeks of August during which period catch rates averaged 112 fish per boat day. Average weight of individual fish caught was 6.8 kg and 60% were in the 5.9 to 7.3 kg range.

V. STOCK ASSESSMENT

A. Catch Trends

Estimated annual catches of North Pacific albacore, by country and gear type, are shown in Table 1 for years 1940 through 1979.

Total catches of North Pacific albacore (Figure 1) showed a variable but increasing trend from 1961 through 1970 and increased substantially from 1971 through 1974. The catch decreased in 1975, reached a peak of nearly 124,000 MT in 1976 and declined to less than 62,000 MT in 1977. Preliminary catch estimates indicate a 1978 total catch of approximately 97,000 MT. The markedly increased catches in the early 1970s are primarily a reflection of increased catches within the Japanese pole-and-line fishery which expanded operations offshore during this period. Japanese longline catches generally increased from the early 1960s until 1967 but show a generally decreasing trend since then. Catches by the North American surface fishery, variable throughout most of the early time series, have steadily declined about 40% from 1972 to 1978.

The yearly mean weights for all fisheries combined (Figure 2) showed no distinct trend throughout the 1960s, decreased from 1971 through 1973 and have been reasonably stable throughout the remainder of the series. The decreases in the 1970s again reflect the offshore expansion by the Japanese pole-and-line fishery and their increased catches of smaller fish. Mean weights in that fishery were variable but without apparent trend until 1969, decreased substantially in 1970 and have been without apparent trend since. Mean weights within the Japanese longline fishery show a generally increasing trend from the early 1950's through 1968. From 1969 through 1975 mean weights in this fishery increased sharply but have declined in 1976 and 1977. Mean weights in the North American surface fishery show no apparent trend throughout the range of data.

B. Effort Trends

Effort trends within each of the three major fisheries have been generally upward (Table 2). In the Japanese pole-and-line fishery effort shows a variable but increasing trend from the early 1960s through 1970 followed by a steeply increasing trend in the 1970s. A method of calculating effective effort was presented by Honma (NPALB/80/5) which may result in improved estimates of effort. Effective effort in the Japanese longline fishery was variable but increasing from 1955 through 1960; decreasing from

1961 through 1964 and increased from 1965 through 1967. Since 1968 effort has generally decreased with increases in 1976 through 1978. Within the North American fishery standardized effort has shown a long-term increase from 1963 through 1977. The extreme variability in the early seventies may be attributable to the introduction of a new statistical reporting system. Table 3 shows the number of Japanese pole-and-line vessels, by size, operating in the Pacific. The number of large vessels is declining.

C. Catch Rate Trends

Catch rates within the Japanese pole-and-line fishery (Table 4) declined from 1962 through 1969 and showed a generally increasing trend from 1970 through 1974 with a peak catch rate that year of approximately 8 MT/fishing day (Figure 3). Catch rates declined substantially from 1975 through 1977 to a level that year of approximately 3 MT/fishing day.

Catch rates within the Japanese longline fishery (Table 4) showed a steady decline from the early 1950s through 1960, increased substantially through 1966 and then declined through 1971. Since then the trend in catch rates has been stable.

Catch rates within the North American fishery, showed no apparent upward or downward trend from 1961 through 1970 but declined from 1971 through 1979. The catch rates are variable over the time period, and the higher variability in the early 1970s may be influenced by variabilities in effort (noted previously).

D. Production Model

The workshop considered results presented in the working papers bearing on the status of the North Pacific albacore stock. A production model analysis by Shiohama (NPALB/80/6) is based on total catch statistics from the Japanese, United States and Canadian fisheries, and a composite abundance index from Japanese longline, pole-and-line, and U. S. surface CPUE data.

Data for the analysis was the same as that used in last year's production model (NPALB/80/16) updated with the most recent statistics available. MSY estimates ranged from about 104,000 MT to 240,000 MT depending on choice of the production model's shape parameter, m . MSY for the best-fit case ($m=2.0$) was 104,000 MT.

As discussed in past workshop reports, the validity of these MSY estimates depends critically on many assumptions which may not be satisfied. Particularly important to the production model is that changes in the index of abundance truly reflect changes in stock size. Further, even if the abundance index used in the analysis is valid, it has varied over such a narrow range that little curvature is seen in the empirical relationship between catch and effort (Figure 4). Thus, precision and reliability of the resulting MSY estimates is low. The production model analysis may give more reliable results if Honma's new effective effort statistics to be estimated for the pole-and-line fishery (NPALB/80/5) are included in future analyses.

E. Yield Per Recruit

A cohort and yield-per-recruit (Y/R) analysis was presented by Bartoo (NPALB/80/1). The analysis which assumes a single North Pacific stock concluded that: (1) following expansion of the Japanese pole-and-line fishery in 1971, Y/R in that fishery increased by about 30%; decreased by about 54% and 23% in the longline and North American fisheries, respectively, with an overall reduction of about 10% (Figures 5-8), (2) it does not appear that, given current fishing patterns, increases in size at recruitment or changes in fishing effort (up to 25%) will produce much increase in overall Y/R. However, fishery specific Y/R in some cases is quite responsive to changes in fishing effort exerted by the individual fleets, and to shifts in age-selectivity of their operations (Table 5). In particular, the two competing surface fisheries harvest fish which might otherwise be caught later in the longline fishery. Thus, changes in intensity of surface fisheries has a relatively great effect on Y/R in the longline fishery. On the other hand, changes in the longline effort would have little impact on Y/R to either of the surface fisheries.

The cohort analysis, assuming a single stock, also suggested that average annual recruitment of 2-year old albacore was about 50% higher in this period 1966-1973 than in the period 1952-1965 (18.9 million fish vs. 12.2 million fish). The impact of the expansion of Japanese pole-and-line fishing in the early 1970s on the catches by North American surface fishery and the longline fishery is not clear due to changes in recruitment.

F. Condition of the Stock

The following discussion assumes a unit North Pacific stock of albacore.

Production model and yield-per-recruit analyses described earlier provide estimates of MSY. Comparison of MSY and the corresponding optimum effort with observed recent catch and effort permits an assessment of stock condition.

The production model analysis suggests that MSY is in the 104,000-236,000 MT range. However, of the these models used to fit the data, the best-fit model fits the data only 6% better than the worst-fit model (Figure 4). So it is impossible to choose objectively a particular MSY from the 104,000-236,000 MT range. Assuming that any MSY in this range is equally likely, the midpoint value, 170,000 MT might be reasonable. Effort corresponding to this MSY is not identified.

An additional estimate of MSY is obtained by multiplying maximum yield-per-recruit and recruitment from cohort and yield-per-recruit analyses. This procedure suggests an MSY in excess of 113,000 MT.

The 170,000 MT estimate of MSY is 40% greater than the maximum historical recorded catch of about 124,000 MT taken in 1976. The 113,000 estimate is 7% less than this maximum. Thus, the comparison of MSY with recent catches suggests that the recent fishery may be operating in the neighborhood of MSY. Previous North Pacific albacore workshops have estimated likely MSY values in the 100,000-130,000 MT. As stated in the past, these MSY

estimates are put forth with a great deal of caution and additional work is needed.

As noted in the 1979 report increasing catches of small albacore may eventually reduce spawning stock size which in turn may reduce subsequent recruitment. Whether the latter will in fact occur cannot be determined until a reliable stock-recruitment model is developed.

VI. OCEANOGRAPHIC PROCESSES AFFECTING FISHERIES AND STOCK ASSESSMENTS

Results of studies of the association of albacore with small-scale ocean parameters (NPALB/80/3) revealed by sonic tagging experiments were presented. The sonic tags, in addition to providing fish position and movement, also provide a readout of either depth or temperature. Surprising results show that albacore can spend long periods in waters as cool as 11°C and brief periods at somewhat cooler temperatures. Tagged albacore were seen to move quickly through a large range of depths, 20 to 180 meters, in which large temperature gradients are experienced. The albacore were found to spend little or no time in the warm surface layer. There were significant day-night differences in behavior; albacore were found to range to greater depths and with large variation during daylight hours. These findings may have an impact on our understanding of stock structure, migration, etc., as concerns temperatures.

The association of albacore with large-scale ocean features was reported (NPALB/80/10). The Subtropical Gyre of the western North Pacific is divided into two subgyres by a thermal ridge in middle latitudes (near 25°N). Spawning of albacore is confined to the southern gyre and the zone of the thermal ridge while the fishery operates both in the north gyre and in the northwest corner of the south gyre. Thus, the thermal ridge zone may act as a boundary to the distribution of immature albacore but not to the adults (Kishi, 1977). Recent research cruises to the central North Pacific have expanded the data base to region east of 160°E where information has been sparse. A preliminary analysis was attempted. The oceanographic division can be seen in maps of the depth of the 18°C surface which is an indicator of the

Subtropical Mode water. The cline which identifies the thermal ridge is steeper to the west of 140°E than to the east. There is a strong year-to-year variation in this structure which may influence the bounds of the fishery.

Efforts by the Japan Meteorological Agency to provide radio facsimile temperature maps based on remote sensing by satellite (NPALB/80/15) were reported. The more valuable and successful aspect of this service is to identify frontal regions. Additional expansion of the coverage will be possible if GOES-3 satellite data can be included in the analysis.

A changing ocean environment may affect the albacore fisheries in four categories:

- A. Influence on the timing and rates of migrations
- B. Variations in distribution (availability) of the stocks
- C. Variations in vulnerability relating the effectiveness of gears to ocean regime.
- D. Influence on spawning and age class survival

VII. SIMULATION MODELING OF NORTH PACIFIC ALBACORE

A new Southwest Fisheries Center initiative is to model the North Pacific Albacore fisheries with variables of the ocean environment as input. All who are interested in this effort are encouraged to join. The effectiveness and success of the model depends on inputs from a broad range of knowledge.

A framework for dynamic modeling of albacore movement and harvesting at various locations and by various gear types was discussed by the workshop. Participants felt that clear statement of purpose was essential for such a project. A model format was proposed and a discussion of various problems on possible approaches followed.

The ocean environment is not to be explicitly modeled as processes but rather as it affects the fish and fisheries by defining changes in rates and timing of movement within the model as functions of ocean

parameters. Examples of specific processes and their relative importance in specific oceanic regions and fisheries were given. The workshop's discussion produced a list of ocean processes likely to be important in the modeling process (Appendix D):

It was observed that a primary objective was to determine how much influence the environment has on the fish and fisheries. The method is to begin with a null hypothesis which is a fishery model that is based on long-term mean conditions. The next step would be to quantify and formulate our best understanding of the effects of changes in parameters of the ocean environment upon elements of the fisheries. These might be introduced as coefficients and functions to alter the model. Improvement in explaining variance would measure the effectiveness of including environmental information in the model.

Purpose of Albacore Fishery/Environment Model

The purpose of the albacore F/E modeling project is to improve the assessment of albacore stocks by 1) making a mathematical statement of current hypotheses on albacore stock dynamics (growth, mortality, recruitment and migration as related to environment) for comparison with observed data (fishery, tagging, oceanographic et al.) as a test of the consistency of these hypotheses; 2) developing alternate hypotheses to explain inconsistencies revealed by 1; and 3) guiding plans for further research to illuminate areas of inconsistency revealed by 1 and 2. Success in the above objectives will lead to improved management advice.

Details of model structure and formulation are shown in Appendix E.

VIII. RECOMMENDATIONS

As a result of discussions and research presented at the Workshop, several research topics were recommended to be undertaken in the next year.

- A. The participants noted that statistics are steadily improving. However, several specific actions should be taken to improve statistics

1. The coverage rate of U. S. west coast albacore data, noted to be dropping, should be measured and steps taken to improve the situation.
 2. Additional statistics on the operation of vessels from the Republic of Korea should be investigated and historical data secured.
 3. The new method of calculating effort for the Japanese pole-and-line fleet, introduced this year, should be used for the entire historical pole-and-line data series.
 4. If possible Canadian CPUE data should be included with U. S. CPUE data in the calculations of effective effort in the North American surface fishery.
- B. The question of stock structure was addressed by research in the last year. However, a definite effort should be made to extend the investigations. The following actions should be taken:
1. Bio-chemical methods for stock identification should be explored and applied to Pacific-wide samples in an attempt to resolve the stock structure questions.

2. Investigate and employ methods which provide information on (a) genetic separation of stocks and (b) behavioral separation of substocks.
 3. Using simulation methods, analyses should be done to examine consistency of various possible stock structure hypotheses with obtained fishing histories.
 4. Examine and describe oceanographic mechanism which cause stock separation.
- C. The participants noted that current research efforts to settle the question of age and growth is forthcoming. It appears that a combination of the "FINRAY" ageing method is quite successful as a means of ageing large numbers of fish. The following actions should be taken:
1. Calibration of "finray" and "daily increment" methods of age determination should be done at once to establish the size at one and two years of age. Tagging data may be of some help.
 2. Apply the methods to samples from more areas.
- D. The participants emphasized that population dynamics analyses should be continued to improve stock assessments. The following actions should be taken:
1. The new index of fishing effort by the pole-and-line fishery should be incorporated in production models.
 2. Yield-per-recruit analyses should be revised to reflect the size-at-age estimated by recent research.

3. Analyses should be done to examine consistency of various possible stock structure hypotheses with observed fishing history.

E. The participants noted the need to identify and quantify environmental parameters which appear to be key processes affecting albacore populations and fisheries. The following specific action should be taken:

1. The environmental and oceanographic variables identified by the Workshop participants in Appendix D as having an effect on the albacore population should be quantified for input into a simulation model.

IX. ARRANGEMENTS FOR NEXT WORKSHOP AND ADJOURNMENT

The Far Seas Fisheries Research Laboratory, Shimizu, Japan, offered to host the Sixth North Pacific Albacore Workshop during the summer of 1981. Meeting dates and other details will be provided by mail.

The draft report of the workshop was adopted by the participants. The meeting was adjourned.

Table 1. Catches for North Pacific albacore in tons, 1940-1979.

Year	Pole-and-line	Japan ² Longline	Other Gear	Total	High-sea	Longline	Taiwan Inshore	Pole-and-line	United States ² Jig ⁵	Sport ⁶	Total	Canada Jig	Total ³
1940													
1941									6,212		6,212	2	6,212
1942									5,266		5,266	34	5,266
1943									10,585		10,585	-	10,585
1944									17,071		17,071	13	17,071
1945									23,948		23,948	210	23,948
1946									17,800		17,800	648	17,800
1947									10,950		10,950	196	10,950
1948									12,234	84	12,318	362	12,318
1949									22,403	113	22,516	987	22,516
1950									24,895	166	25,061	1,012	25,061
1951	16,463								32,847	866	33,713	961	33,713
1952	41,386	25,687	237	68,710					15,629	557	16,186	86	16,186
1953	32,921	27,777	132	60,830					23,843	1,373	25,216	71	25,216
1954	28,069	20,958	38	49,065					15,740	171	15,911	5	15,911
1955	24,236	16,277	136	40,649					12,246	147	12,393	-	12,393
1956	42,810	14,341	57	57,208					13,264	577	13,841	-	13,841
1957	49,500	21,053	151	70,704					18,751	482	19,233	17	19,233
1958	22,175	18,452	124	40,731					21,165	304	21,469	8	21,469
1959	14,252	15,502	67	30,121					14,855	48	14,903	74	14,903
1960	23,156	17,369	76	42,601					20,990	-	20,990	212	20,990
1961	18,636	17,437	268	36,341					20,100	557	20,657	5	20,657
1962	8,729	15,764	191	24,684					12,054	1,355	16,246	4	16,246
1963	26,420	13,464	218	40,102					19,753	1,681	22,519	1	22,519
1964	23,858	15,458	319	39,635					25,142	1,161	28,735	5	28,735
1965	41,491	13,701	121	55,313	26				18,389	824	22,624	3	22,624
1966	22,830	25,050	585	48,465	16				16,461	731	17,609	15	17,609
1967	30,481	28,869	520	59,870	16				15,169	588	17,357	44	17,357
1968	16,597	23,961	1,109	41,667	17				17,814	707	22,634	161	22,634
1969	31,912	18,006	1,675	51,593	15				20,441	951	26,298	1,028	26,298
1970	24,263	15,372	1,069	40,704	21				18,826	358	22,180	1,365	22,180
1971	52,957	10,915	1,623	65,495	23				21,039	822	26,277	354	26,277
1972	60,591	12,622	1,120	74,333	25				22,496	1,175	25,442	1,587	25,442
1973	69,640	16,000	2,152	87,792	35				23,600	637	27,987	3,558	27,987
1974	73,576	12,952	1,390	87,918	40				15,652	72	17,960	1,270	17,960
1975	52,157	9,931	697	62,785	28				20,177	739	25,693	1,207	25,693
1976	85,336	15,738	2,622	103,696	37				18,926	1,243	23,412	101	23,412
1977	31,934	15,512	1,952	49,398	524				16,314	766	19,780	252	19,780
1978	59,817	12,888	7,411	80,176	6				10,012	619	12,128	53	12,128
1979 ⁴	43,000	-	-	-	35				15,700	756	16,650	23	16,650
1979 ⁵									-	-	6,632	521	6,632

¹Japanese longline catch for 1961-68 excludes minor amount taken by vessels under 20 gross tons. Longline catch in weight is estimated by multiplying annual number of fish caught by an average weight statistic.

²United States pole-and-line catch excludes minor amount taken by vessels not submitting log books to IATTC; this amount is included in the jig catch.

³Omitted are unknown but minor catches by longline and pole-and-line vessels of the Republic of Korea and Taiwan.

⁴1979 figures are preliminary.

⁵All gears 1940-1960 added together.

⁶Estimated minimum based on partial coverage rate.

Table 2. Estimated effective effort by fishery for
North Pacific albacore in years 1961-1968.

Year	Japan Longline (hooks x 10 ⁶)	Japan ¹ Pole-and-line (days)	U.S. ¹ Effort (days)
1952	283.0		
1953	311.1		
1954	409.6		
1955	395.3		
1956	389.1		
1957	346.4		
1958	384.3		
1959	373.7		
1960	455.5		
1961	432.0	4,235	25,255
1962	309.0	1,209	27,464
1963	259.0	4,200	31,456
1964	232.4	3,478	30,355
1965	242.7	6,628	24,945
1966	276.8	3,843	25,756
1967	434.8	5,005	26,453
1968	355.8	3,108	29,175
1969	361.2	6,447	28,528
1970	253.2	3,958	20,165
1971	255.2	7,631	44,015
1972	186.7	9,695	67,319
1973	173.5	12,685	32,031
1974	153.8	9,421	39,748
1975	158.1	8,766	35,449
1976	227.2	13,921	38,445
1977	256.2	10,609	32,292
1978	252.8	16,725	32,111

¹Japanese pole-and-line days are not the same as U. S. effort days.

Table 3. Number of Japanese pole-and-line vessels by size.

Year	Total number	Total number (>20 tons)	Size of Vessel (gross tons)				
			<20	20-50	50-100	100-200	200<
1961	5523	477	5046	141	132	178	26
1962	4460	451	4009	186	111	126	28
1963	6533	492	6041	240	111	112	29
1964	4361	532	3829	291	103	106	32
1965	4226	572	3654	298	91	148	35
1966	4191	571	3620	299	71	167	34
1967	4114	564	3550	296	54	173	41
1968	3231	561	2670	276	60	170	55
1969	4008	533	3475	242	71	158(2)	56(3)
1970	3666	518	3148	220	91	143(3)	64(3)
1971	3684	516	3168	165	133	132(3)	86(3)
1972	4156	560	3596	131	162	119(3)	148(3)
1973	3587	589	2998	93	211(1)	83(3)	202(3)
1974	3941	716	3225	136	269	84	227
1975	3344	696	2648	95	283	39	279
1976	3754	653	3101	51	318	17	267
1977	4010	662	3348	40	348	13	261
1978	3680	645	3035	26	358	10	251

() shows the number of prefectural research vessels included.

Table 4. Actual CPUE¹ statistics for major North Pacific albacore fisheries, 1961-1979.

Year	Japan Pole-and-line	United States jig	Japan Longline		
			"Young" ² area(2)	"Adult" area(3)	Entire area(4)
1961	4.40	69.17	0.55	0.14	0.25
1962	7.22	124.59	0.67	0.14	0.30
1963	6.29	132.09	0.68	0.19	0.32
1964	6.86	97.61	0.90	0.19	0.40
1965	6.26	89.07	0.70	0.25	0.33
1966	5.94	90.45	1.20	0.27	0.54
1967	6.09	126.83	0.88	0.29	0.40
1968	5.34	135.23	0.84	0.29	0.38
1969	4.95	112.57	0.60	0.31	0.28
1970	6.13	127.39	0.66	0.27	0.31
1971	6.94	96.68	0.43	0.22	0.21
1972	6.25	61.08	0.63	0.30	0.30
1973	5.49	82.89	0.85	0.30	0.38
1974	7.81	105.17	0.64	0.30	0.34
1975	5.98	99.81	0.46	0.21	0.23
1976	6.13	69.22	0.66	0.21	0.30
1977	3.01	59.90	0.60	0.14	0.26
1978	3.58	86.80	0.52	0.17	0.23
1979	3.50	45.41	-	-	-

¹Unit: MT/vessel-day for Japan pole-and-line; fish/vessel-day for United States jig; fish/100 hooks for Japan longline.

(2) "Young" area is 25°-45°N from October to March and 30°-45°N from April to September.

(3) Adult are: 10°-25°N

(4) Entire area: 0°-45°N

Table 5. Yield-per-recruit in kg. of North Pacific albacore by fishery. Estimated by multiplying each fisheries average age-specific instantaneous fishing, mortality rate for the 1966 through 1973 cohorts by differing proportions.

		North American Fishery Proportional Multiplier					Fishery
		1.1	1.0	.9	.7	.4	
Longline Fishery Proportional Multiplier ¹	1.1	.73	.77	.81	.90	1.06	Longline
		1.30	1.21	1.11	.91	.56	North American
		2.58	2.66	2.75	2.95	3.27	Pole-&Line
		4.60	4.64	4.68	4.76	4.90	Entire Fishery
	1.0	.71	0.75	.79	.88	1.04	Longline
		1.30	1.21	1.12	.91	0.56	North American
		2.59	2.68	2.77	2.97	3.30	Pole-&Line
		4.60	4.64	4.68	4.76	4.90	Entire Fishery
	.85	.67	.71	.75	.84	.99	Long line
		1.30	1.21	1.12	.91	.56	North American
		2.62	2.71	2.80	3.00	3.34	Pole-&Line
		4.60	4.63	4.67	4.67	4.89	Entire Fishery
	.75	.65	.69	.72	.81	.95	Longline
		1.30	1.22	1.12	.92	.57	North American
		2.64	2.73	2.82	3.02	3.36	Pole-&Line
		4.59	4.63	4.67	4.75	4.88	Entire Fishery
	.6	.62	.66	.69	.78	.92	Longline
		1.31	1.22	1.12	.92	.57	North American
		2.65	2.75	2.84	3.04	3.39	Pole-&Line
		4.58	4.62	4.66	4.74	4.87	Entire Fishery

¹Pole & Line = 1.0 for All Cases

		North American Fishery Proportional Multiplier					Fishery
		1.1	1.0	.9	.7	.4	
Pole-and-Line Fishery Proportional Multiplier ¹	1.1	.62	.65	.69	.77	.90	Longline
		1.25	1.17	1.07	.88	.54	North American
		2.68	2.77	2.87	3.07	3.40	Pole-&Line
		4.55	4.59	4.63	4.71	4.84	Entire Fishery
	1.0	.71	0.75	.79	.88	1.04	Longline
		1.30	1.21	1.12	.91	.56	North American
		2.59	2.68	2.77	2.97	3.30	Pole-&Line
		4.60	4.64	4.68	4.76	4.90	Entire Fishery
	.9	.82	.86	.91	1.01	1.20	Longline
		1.35	1.26	1.16	.95	.59	North American
		2.48	2.57	2.66	2.85	3.17	Pole-&Line
		4.65	4.69	4.73	4.82	4.95	Entire Fishery
	.7	1.09	1.15	1.21	1.35	1.79	Longline
		1.46	1.36	1.26	1.03	1.55	North American
		2.20	2.28	2.36	2.54	1.61	Pole-&Line
		4.75	4.79	4.84	4.93	4.96	Entire Fishery
	.4	1.70	1.79	1.90	2.12	2.51	Longline
		1.66	1.55	1.44	1.18	.74	North American
		1.55	1.61	1.68	1.81	2.03	Pole-&Line
		4.91	4.96	5.01	5.12	5.28	Entire Fishery

¹Longline = 1.0 For All Cases

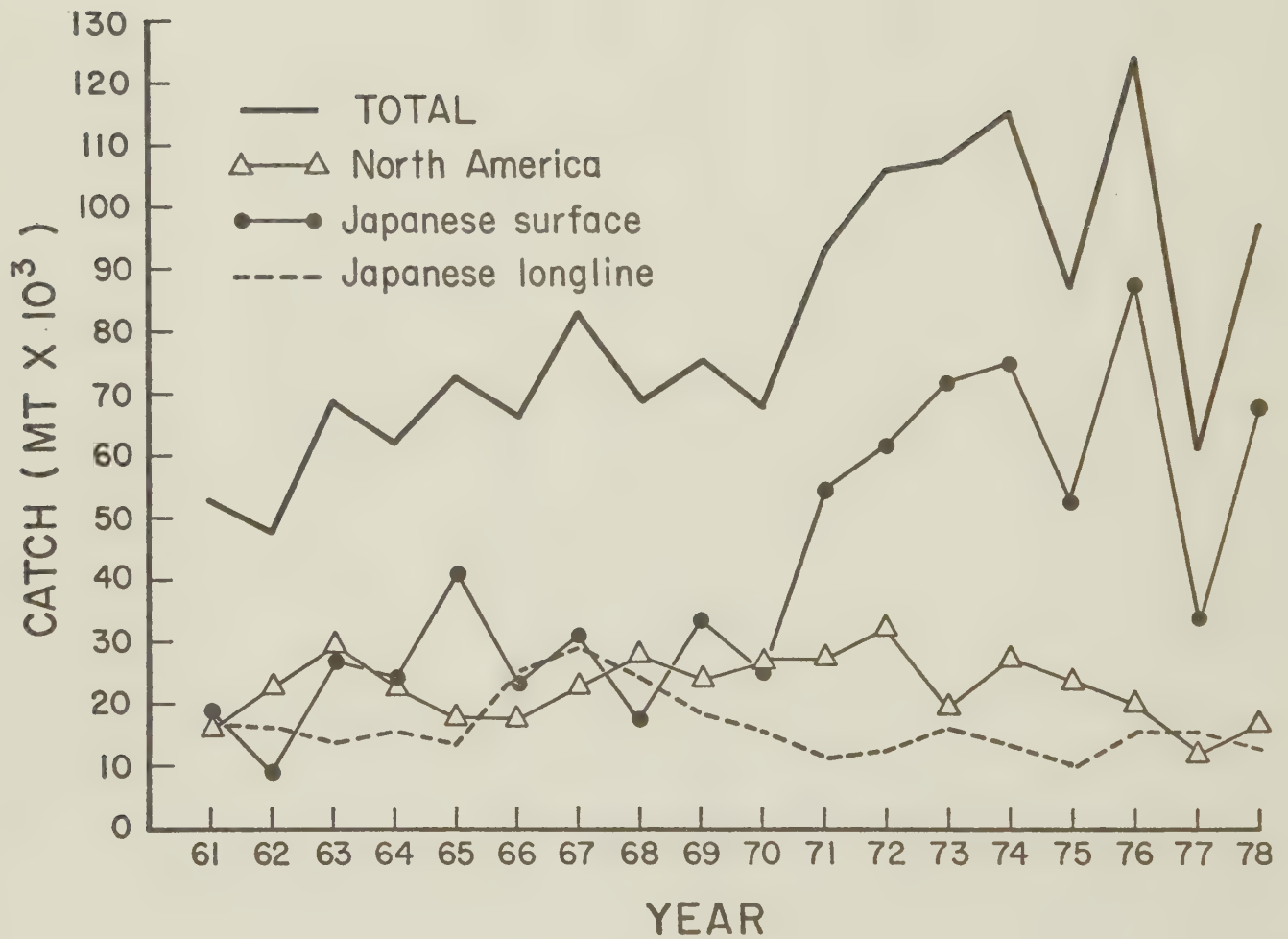


Figure 1. Yearly catches of North Pacific albacore, by weight, of Japanese longline, Japanese pole-and-line, and North American surface fisheries for years 1961-1978.

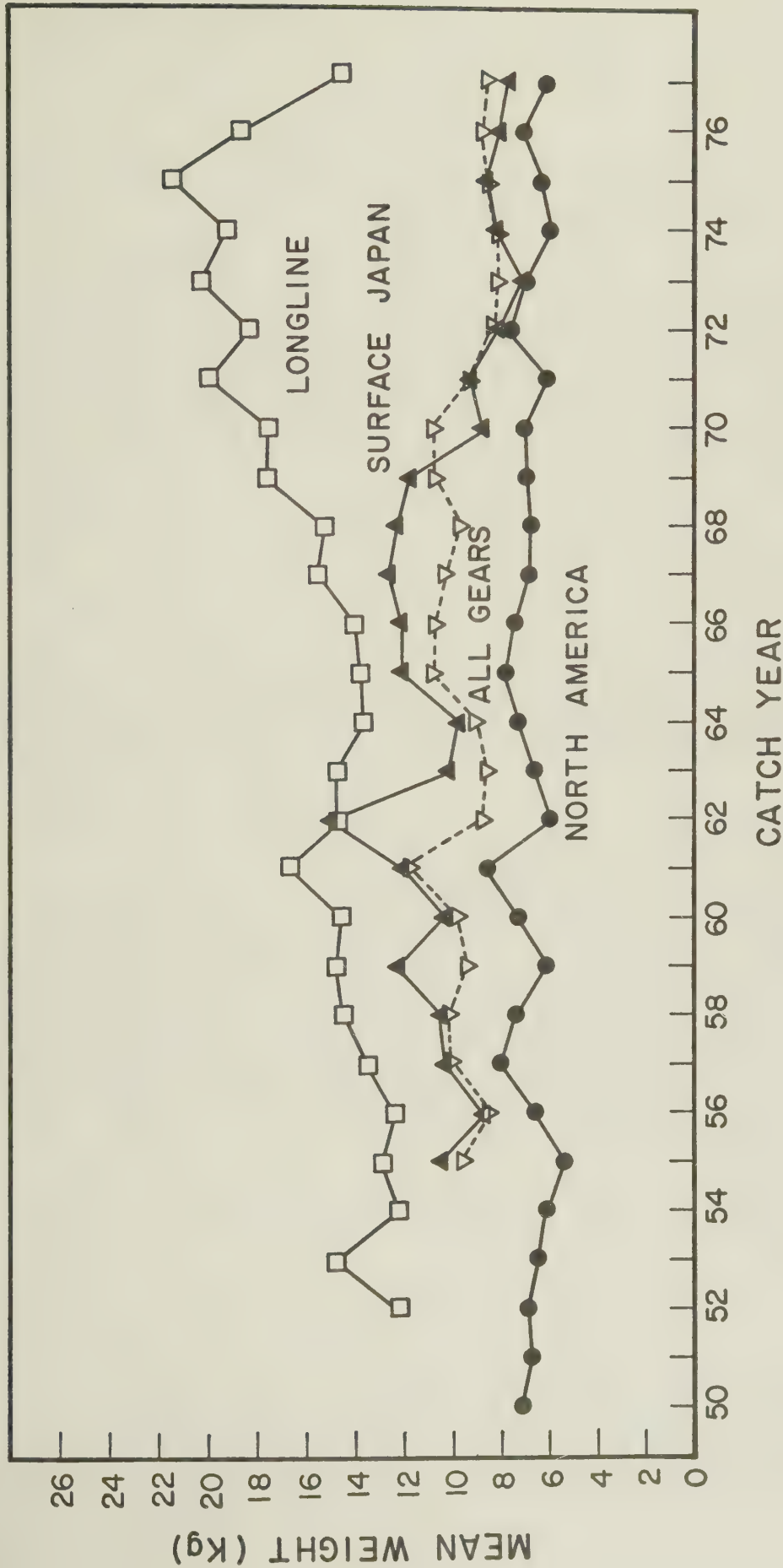


Figure 2. Yearly mean weights of North Pacific albacore caught by the Japanese longline, Japanese pole-and-line and North American surface fisheries, and the weighted mean for all three fisheries combined, versus time.

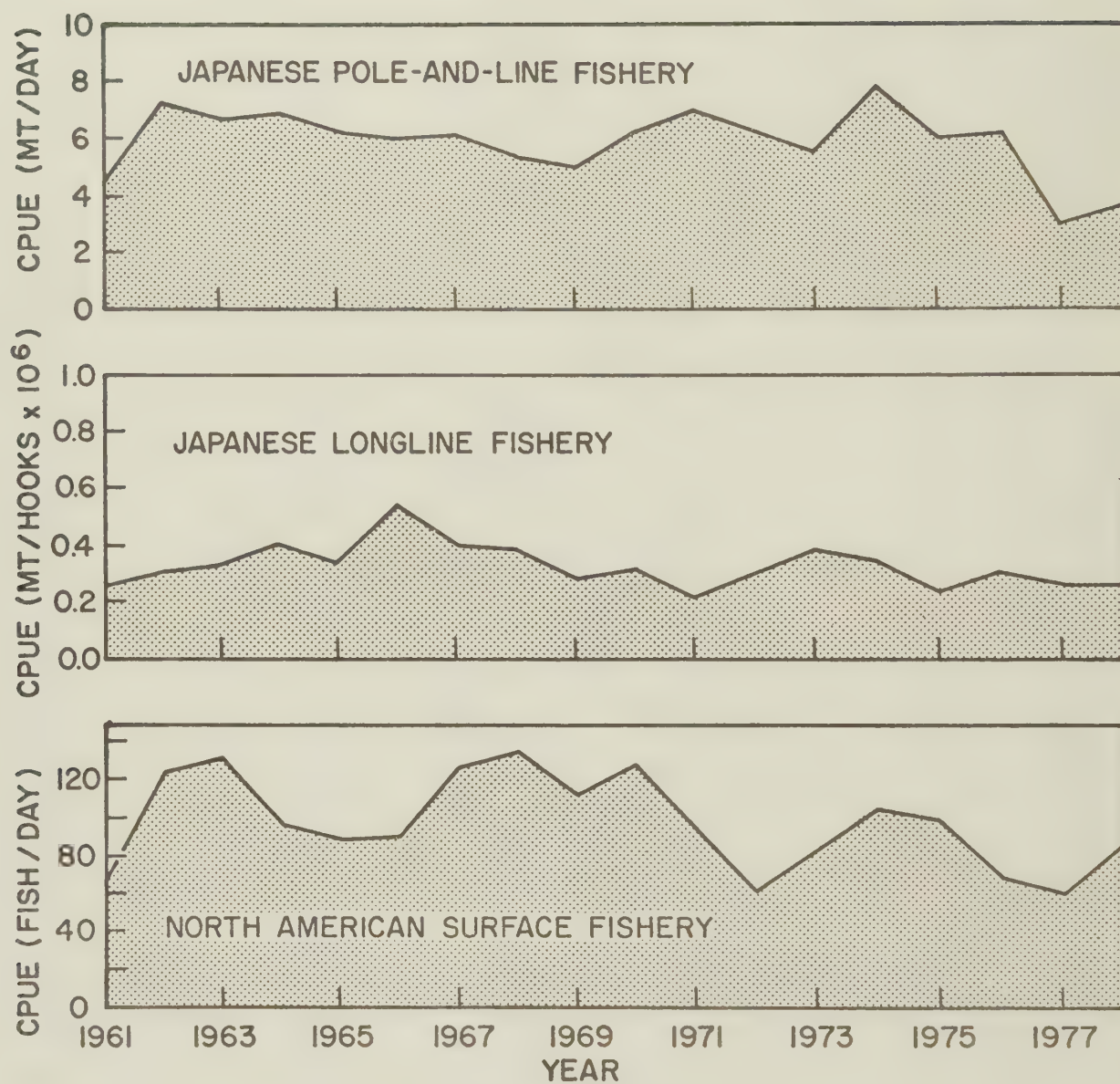


Figure 3. Yearly catch rates of North Pacific albacore in the Japanese pole-and-line, Japanese longline and North American surface fisheries for years 1961-1978.

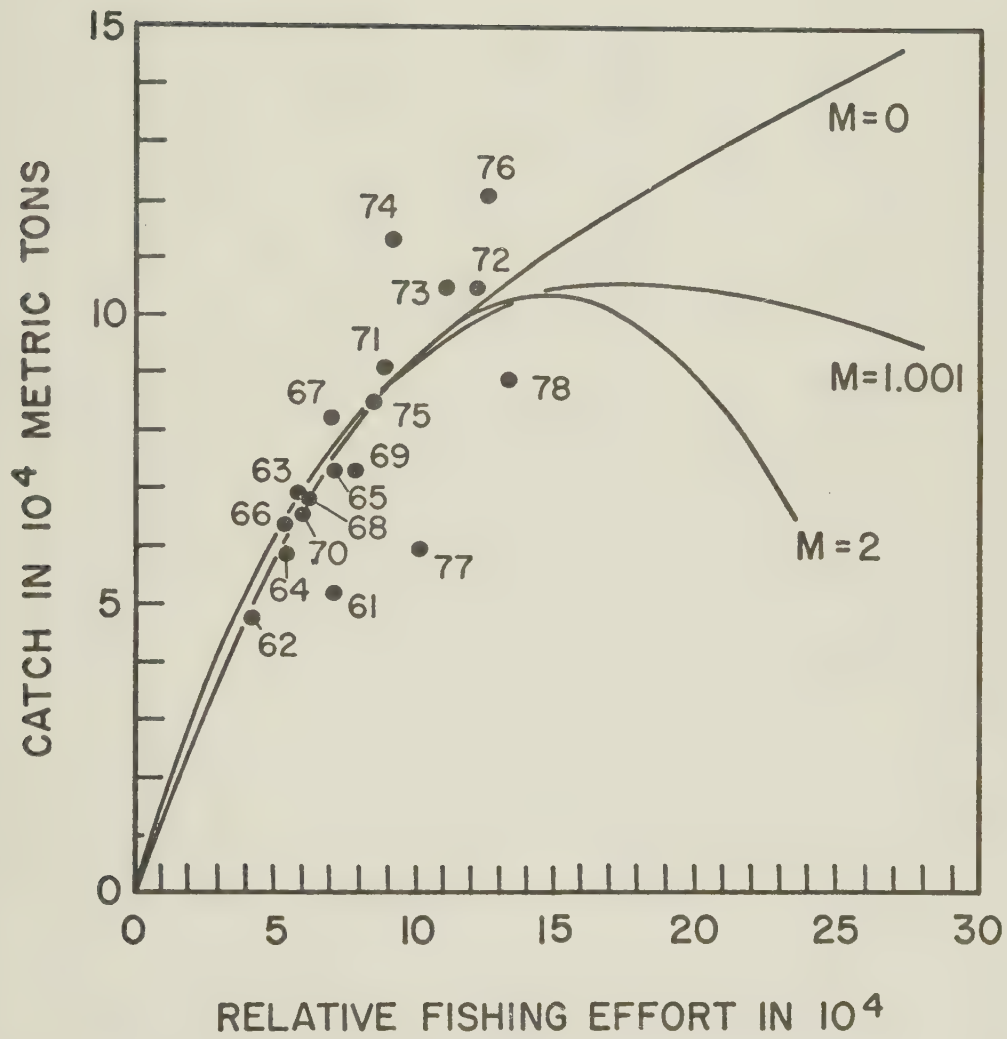


Figure 4. Equilibrium yield curves and observed data for North Pacific albacore, 1961-1978.

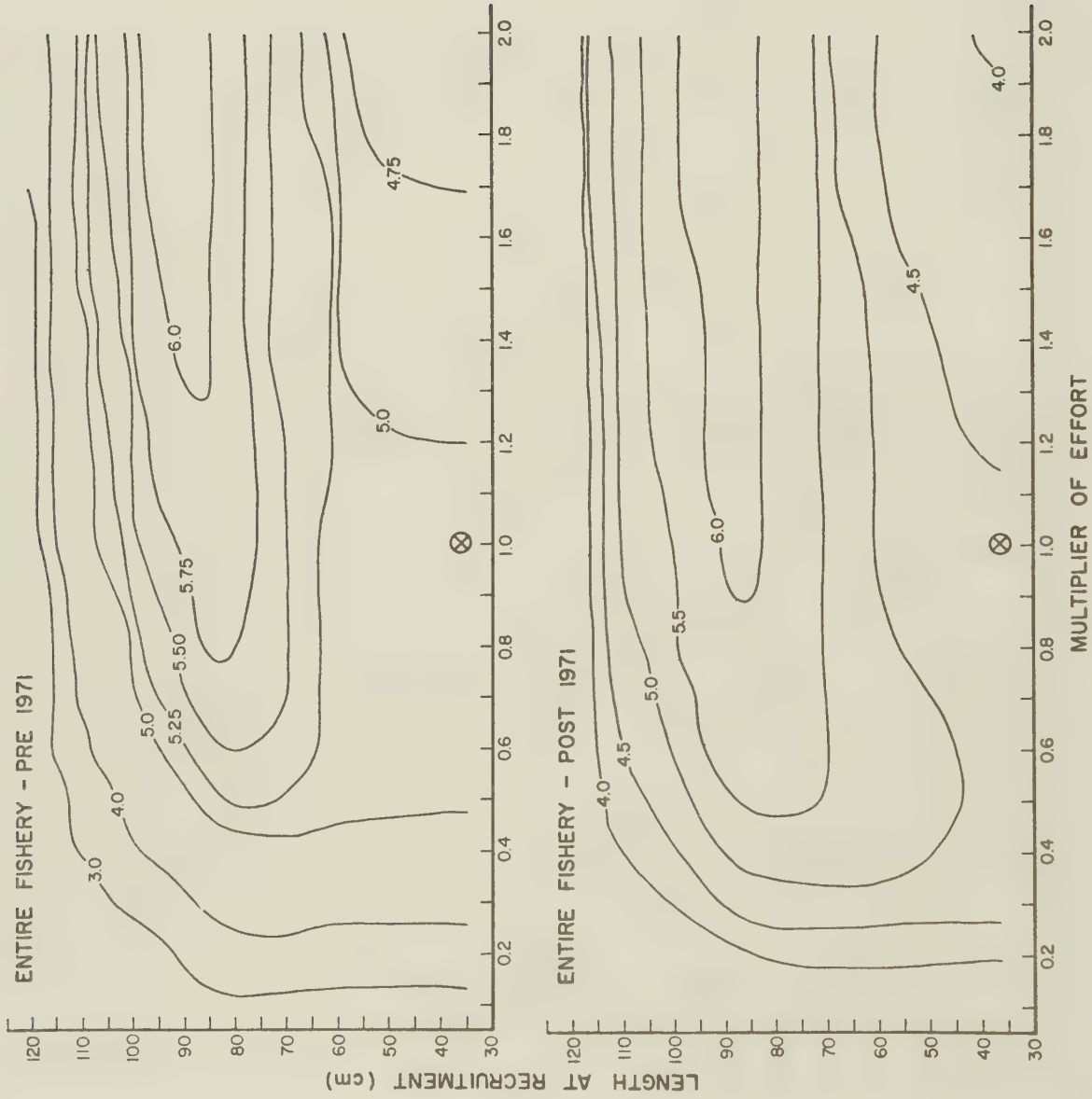


Figure 5. Estimated yield-per-recruit, as functions of age at recruitment and fishing mortality vector multiplier, of North Pacific albacore taken before and after 1971 by all gears combined.



Figure 6. Estimated yield-per-recruit, as functions of age at recruitment and fishing mortality vector multiplier, of North Pacific albacore taken before and after 1971 by the North American surface fishery.

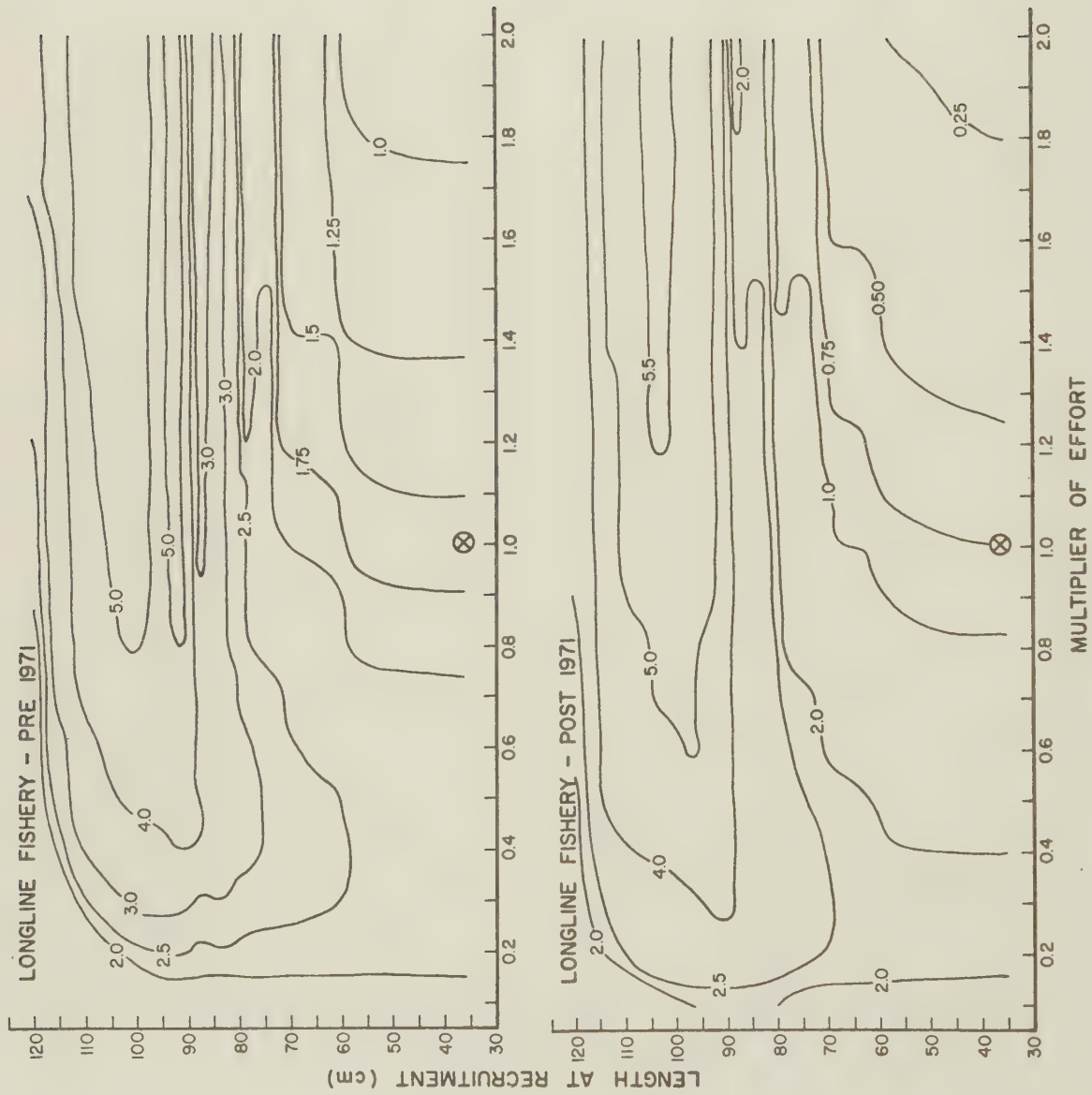


Figure 7. Estimated yield-per-recruit, as functions of age at recruitment and fishing mortality vector multiplier, of North Pacific albacore taken before and after 1971 by the longline fishery.

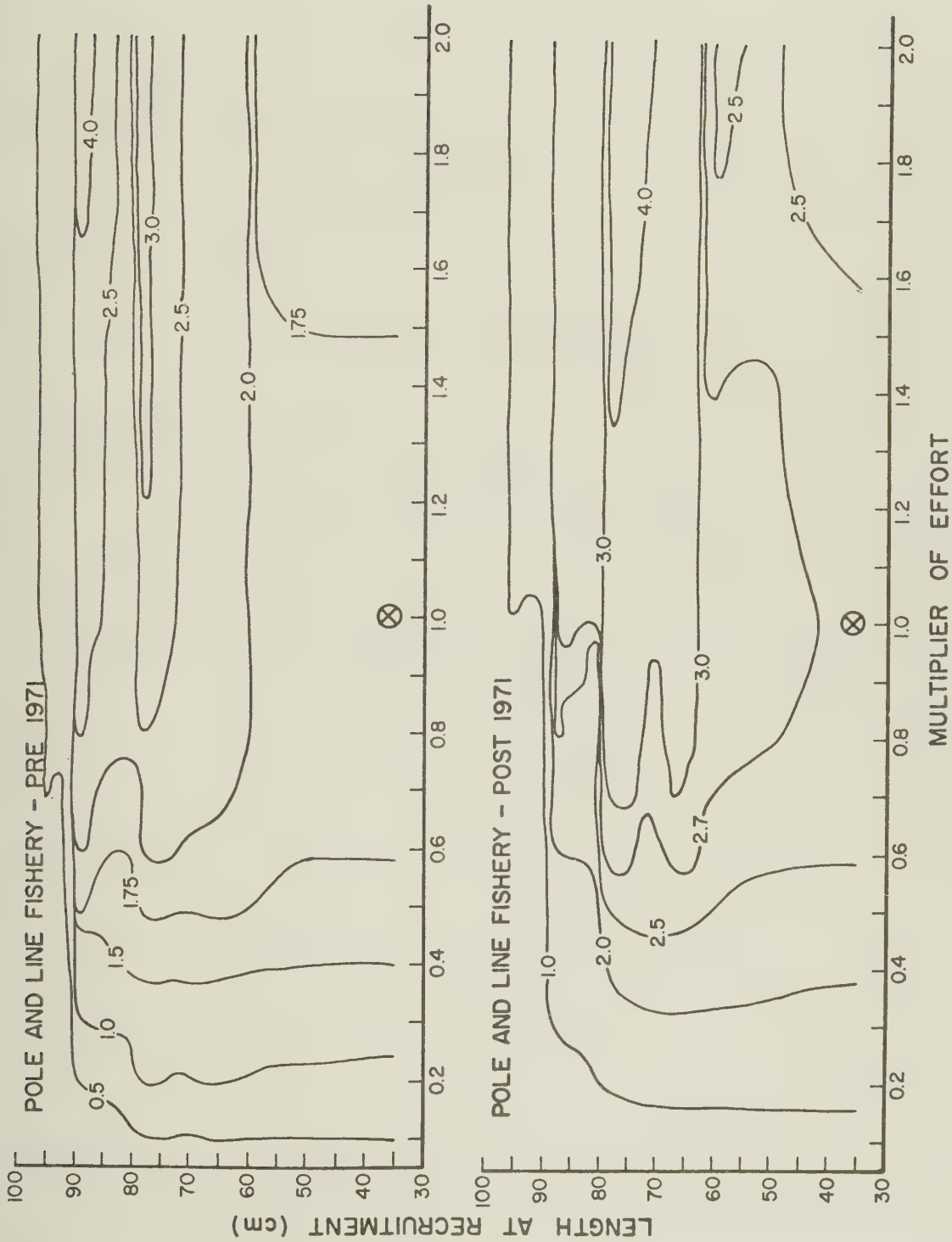


Figure 8. Estimated yield-per-recruit, as functions of age at recruitment and fishing mortality vector multiplier, of North Pacific albacore taken before and after 1971 by the Japanese surface fishery.

APPENDIX A
FIFTH NORTH PACIFIC ALBACORE WORKSHOP
List of Participants

N. Bartoo, National Marine Fisheries Service/Southwest Fisheries Center
S. Bledsoe, University of Washington, College of Fisheries
B. Culver, Washington Department of Fisheries, Montesano
F. Hagerman, California Department of Fish and Game, Long Beach, CA
M. Honma, Far Seas Fisheries Research Laboratory
L. Hreha, Oregon Department of Fish and Wildlife
K. Ketchen, Canada Department Fisheries & Oceans, B.C.
S. Kume, Far Seas Fisheries Research Laboratory
R. Michael Laurs, National Marine Fisheries Service/Southwest Fisheries Center
R. Lynn, National Marine Fisheries Service/Southwest Fisheries Center
W. Parks, National Marine Fisheries Service/Southwest Fisheries Center
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E. Weber, National Marine Fisheries Service/Southwest Fisheries Center
J. Wetherall, National Marine Fisheries Service/Southwest Fisheries Center
I. Yamanaka, Far Seas Fisheries Research Laboratory
Rong-Tszong Yang, Taiwan University

APPENDIX B
FIFTH NORTH PACIFIC ALBACORE WORKSHOP
SOUTHWEST FISHERIES CENTER
La Jolla, California

WORKING AGENDA

Monday

- 9:00 a.m. -Meeting Opening
 -Adoption of Agenda
 -Assignment of Writing Tasks
 -Exchange Data
- 12:00 noon *Lunch
- 1:00 p.m. -Discussion of Current Fishery
 -Discussion of Stock Assessment Papers
 -Evaluation of Current State of the Stock
- 4:30 p.m. -Adjourn

Tuesday

- 8:30 a.m. -Stock Assessment Rapporteurs Report
 -Discussion of Age and Growth Work
 -Discussion of Tagging, Stock Structure, and Biological Work
- 12:00 noon *Lunch
- 1:30 p.m. -Discussion of Oceanographic Processes Affecting Fisheries and Data
 -Discussion of Simulation Modeling of North Pacific albacore
- 4:30 p.m. -Adjourn for dinner
- 6:00 p.m. Reconvene for Evening Session
- 9:00 p.m. -Continue Tuesday's Topics
 -Adjourn

Wednesday

- 8:30 a.m. -Preparation of Sections of Draft of Report
- 12:00 noon *Lunch
- 1:00 p.m. -Finish Report Drafts
 -Adjourn for tour of cannery and zoo

Thursday

- 8:30 a.m. -Read and Review Draft Report
 -Draft Changes
- 11:30 a.m. *Lunch
- 1:00 p.m. -Read and Review Draft Changes
 -Approve Draft Report
- 4:30 p.m. -Adjourn

*From The Cheese Shop as desired
Tea and coffee will be served on mid-morning and mid-afternoon breaks

APPENDIX C
LIST OF DOCUMENTS

<u>Ref. No.</u>	<u>Author</u>	<u>Title</u>
NPALB/1/80	N. Bartoo	Estimated yield-per-recruit of North Pacific Albacore
NPALB/2/80	E. Weber	An evaluation of fishery indicators for North Pacific albacore (<u>Thunnus alalunga</u>)
NPALB/3/80	R.M. Laurs & Assoc.	Reports for the Fifth North Pacific Albacore Workshop
NPALB/4/80	T. Shiohama	On the migration of North Pacific albacore estimated from the tagging results, 1972-79
NPALB/5/80	M. Honma	A preliminary investigation on fishing effort of Japanese albacore pole-and-line fishery in the North Pacific Ocean
NPALB/6/80	T. Shiohama	A brief stock assessment of North Pacific albacore by generalized production model
NPALB/7/80	M. Asano	Change of albacore baitboat fishing in the Northwest Pacific Ocean
NPALB/8/80	T. Shiohama	Review of the current Japanese North Pacific albacore fisheries, 1980
NPALB/9/80	R. Yang	Albacore catch by Taiwan's tuna longline fishery in North Pacific
NPALB10/80	I. Yamanaka H. Yamanaka M. Yukinawa J. Morita	Analysis of oceanographic conditions in the Western and Central North Pacific by data obtained by prefectural tuna investigation vessels
NPALB/11/80	M. Asana	Change of albacore baitboat fishing in the Northwest Pacific Ocean (in Japanese)
NPALB/12/80	K. Ketchen	Preliminary report on the use of dorsal finray cross-sections to estimate the age of North Pacific albacore
NPALB/13/80	K. Ketchen	Report on the Canadian fishery for albacore in 1979
NPALB/14/80	J. Wetherall M. Yong	Exploitation of North Pacific albacore by Korean and Taiwanese longliners based in American Samoa

- | | | |
|-------------|------------------------|--|
| NPALB/15/80 | I. Yamanaka | Application of Japanese Geostational
Satellite GMS-1 (Himawari) for Fisheries
Oceanography |
| NPALB/16/80 | N. Bartoo
S. Kikawa | Report of the Fourth North Pacific
Albacore Workshop, Shimizu, Japan,
June 25-27, 1979 |

APPENDIX D

Ocean Processes Likely to Affect North Pacific Albacore Populations

Kuroshio Meander Pattern

Oyashio-Kuroshio frontal structure

Kuroshio Extension frontal structure

Transition Zone frontal structure

Ocean thermal structure (a) as related to initial warming
(b) seasonal cooling and (c) wind stress

California Current transport

Coastal upwelling

Upwelling and other fronts

Weather

APPENDIX E

Albacore Simulation Model

Mathematical Structure of the Model

The model will follow standard methods of age-structured differential equation modeling for fish stocks with the addition of a migration mechanism for movement of stocks between areas of the North Pacific. Let N_i be the number density of fish in area i (the age subscript has been deleted for simplicity); then the basic differential equation for stock dynamics is

$$\frac{d}{dt} N_i = -(m_i + \sum_j q_{ij} f_{ij}) N_i + \sum_j a_{ji} N_j$$

Where: m_i is natural mortality (yr^{-1})
 q_{ij} is catchability of fish in area i by gear j
 f_{ij} is amount of fishing by gear of type j in area i
 a_{ji} is migration rate coefficient from area i to area j ,
 $i \neq j$ (yr^{-1})

All of the above coefficients are both age specific and time dependent in addition to the area and gear dependencies shown by the subscripts.

Recruitment to the fishery is handled by initializing the age 1 differential equation with an amount of fish determined by least squares techniques as that which gives the best fit of predicted to observed catch by length. Mortality and catchability are similarly determined; weight and length at age are to be determined by previously developed relations. The catch (C_{ij} , area i and gear j) equation in differential form is

$$\frac{d}{dt} C_{ij} = q_{ij} f_j N_i$$

The migration coefficient matrix, $[a_{ji}]$ allows for a closed system of fish moving among areas. The closed system is guaranteed by requiring what

$$a_{ii} = -\sum_j a_{ij}$$

The migration coefficient is related to a dimensionless time function, $a_{ij}^*(t)$, by normalizing with apparent long distant swimming speed, $\bar{S}$ and

distance between areas d_{ij}

$$a_{ij} = a_{ij}^* (t) \cdot \bar{S}/d_{ij}$$

Timing and duration of migrations is then controlled by development of functional relations between a^* and time for an initial autonomous model to serve as a null hypothesis against which to test theories of environmental control of migration patterns. The nonautonomous version, continuing such theories, will have functional relations between a^* and environmental functions such as timing of oceanographic front movement, location of temperature isotherms etc..

For example, an observed phasing of fishing activity in hypothetical areas such as shown in Figure 8 would be produced by the functional relation between a^* and time as shown in Figure 1. The equation for such a relation might be as shown below:

$$a^* = a_{\max}^* e^{-1/2(\frac{t-t_0^2}{a_w^*})}$$

Parameters $a_{\max}^*$, t_0 and a_w^* are to be determined from data and least squares techniques. The time dependency in equation (4) would be replaced by an oceanographic parameter or index, itself time dependent, in the nonautonomous version.

The complexity of determination of appropriate environmental parameters was recognized by the participants. It will probably be necessary to synthesize a^* as a function of several variables. Though this will be a difficult and frequently fruitless task, it was felt that the model development was necessary because there are no good alternatives with which to perform a comprehensive objective test of theories about the environmental correlates of albacore behavior.

Preliminary Area Breakdown and Fishery/Fish Migration Phasing

An earlier report¹ contained draft area-fishery breakdown for guidance in

¹Minutes of planning session on development of fish/fishery/environment model for North Pacific albacore, SWFC 27-28 Nov. 1979, R. Michael Laurs.

initial model development. This was refined considerably by the workshop and tabulations of fishery time and area phasing as well as an initial (environmentally autonomous) migration scheme were developed. Figure 2 shows the area breakdown; Table 1 shows the time and area phasing of the various fisheries. Table 2 gives a simplified scheme of movement of fish between areas which is thought consistent with tagging data presented at the workshop. These initial schemes are not intended to be comprehensive of all migration paths and all fisheries but is rather an approximation to allow model development to begin. Refinements are expected to be more easily introduced after a preliminary model has been designed and computer implemented.

APPENDIX E

Table E1. Area, fishery, fishery timing and ages in catch suggested for initial albacore model development. Areas correspond to Figure 8. Gear code: PL-Pole-and-line, LL-Longline, JG-Jig.

Area	Gear	Fishery dates	Catch ages (yrs)
1	PL	April-July	1, 2, 3, 4, 5
	LL	October-March	4, 5, 6, 7
2	PL	May-August	1, 2, 3, 4, 5
	PL	October-December	2, 3, 4, 5
	JG	May-August	1, 2, 3, 4, 5
	LL	October-January	4, 5, 6, 7
3A	LL	June-August	6, 7
3B	LL	April-June	6, 7
4	LL	January-December	6, 7
5	JG	July-November	1, 2, 3, 4, 5
	PL	August-October	2, 3, 4, 5
6	JG	July-October	2, 3, 4, 5
	PL	August-October	2, 3, 4, 5
7	Not Used		
8	LL	October-March	4, 5, 6, 7

APPENDIX E

Table E2. Hypothetical sequential movement of albacore by age and area (see Figure 8).

Northern Migration Age	Route Area	Southern Migration Age	Route Area
1	2 8*	1	4* 5
2	2 8*	2	8* 5
3	6 1 2 8*	3 4	8* 5 8 5
4	6 1	5	8 4
5	2 8 6	6	4
6	1 3A-3B		

Cross Movement

Cross Movement?

*Indicates albacore not harvested in this age-area stratum.

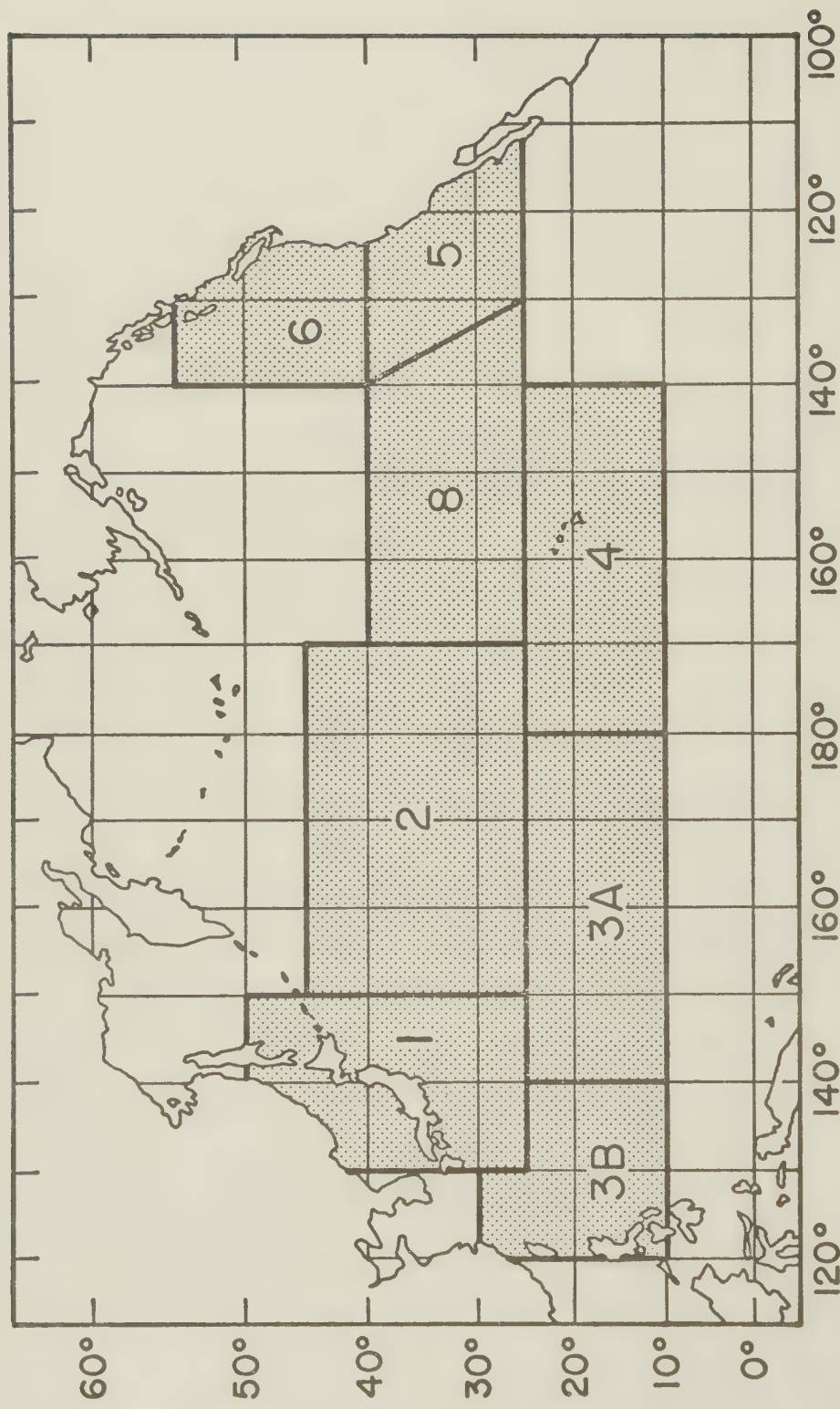


Figure E1. Area breakdown of North Pacific albacore fishing grounds for simulation model development.

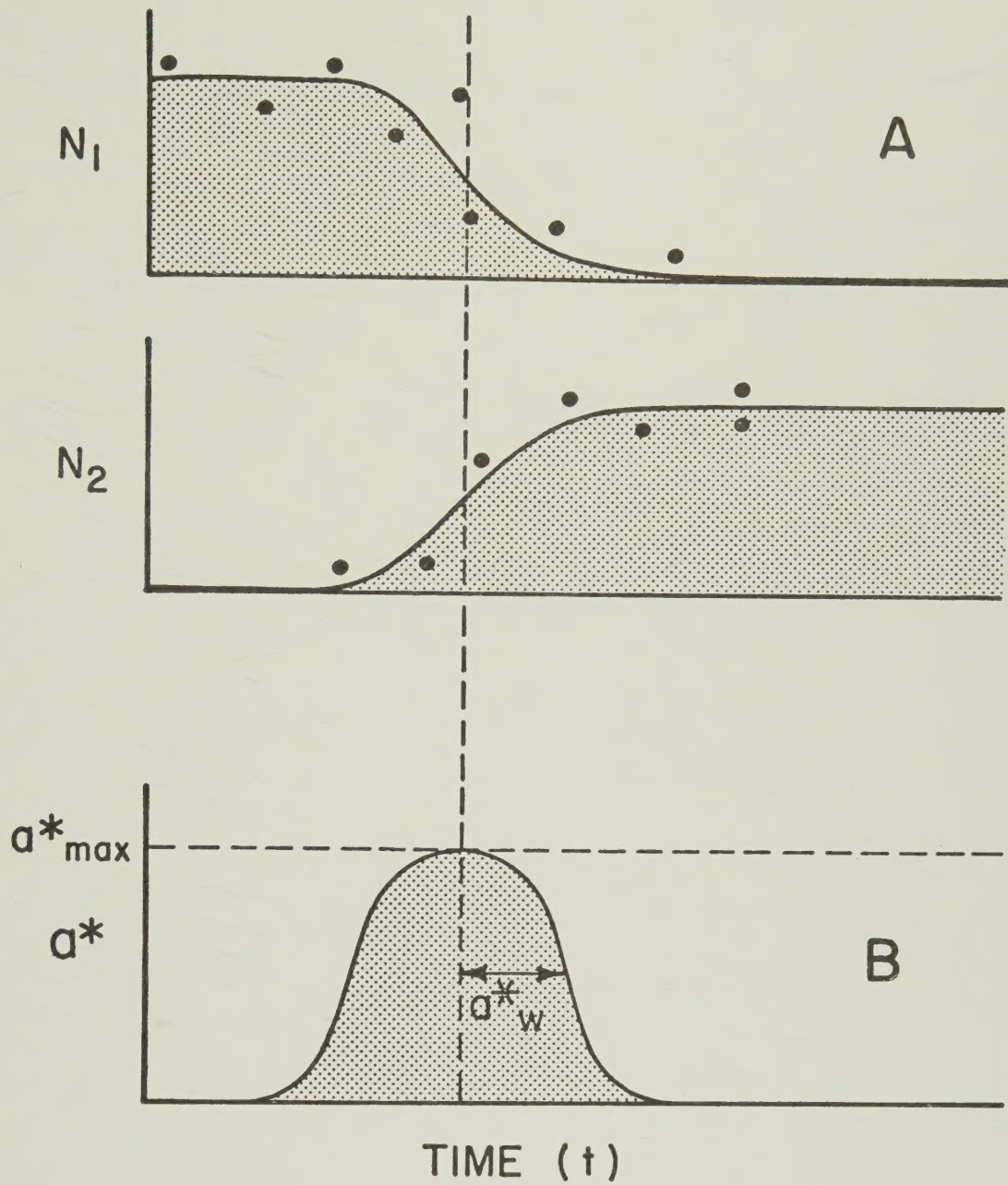


Figure E2. Example of development of migration coefficient for autonomous version of model. A shows the observed and predicted stock densities in two areas, (*=observed,--predicted). B shows functional relation between a^* and time which gives results in A (see text).

